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Laboratory Method to Estimate Hydrogen Chloride Emission Potential Before Incineration of a Waste

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LABORATORY METHOD TO ESTIMATE HYDROGEN CHLORIDE EMISSION POTENTIAL BEFORE INCINERATION OF A WASTE

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A laboratory method has been developed to provide an estimate of the amount of hydrogen chloride gas that will form during incineration of a waste. The method involves incineration of a sample of the waste at 900 C in a tube furnace, removal of particles from the resulting gases by filtration at 250 F (120 C), collection of hydrogen chloride gas in a water-filled impinger, and measurement of the collected HCl as chloride using a standard ion chromatography/conductimetric detection method. Duplicate experimental runs were conducted with quartz and with INCONEL components in the incineration zone of the apparatus. The two materials gave quite different results, which indicates some surface phenomenon may be involved.

Results with quartz components indicated that organochlorine is essentially completely converted to HCl. Very ionic inorganic chlorides (e.g., KCl and NaCl) formed little or no HCl when incinerated in zero grade air (3ppm water and 1 ppm total hydrocarbon) but gave large amounts of HCl (20-80% conversion) if the incineration atmosphere contained 2.4-5.0% water vapor, which contains hydrogen for HCl formation. Results with less ionic inorganic chloride ($FeCl_3$) and with chlorine in a positive oxidation state (NaCl solution) indicated significant conversion to HCl, especially in the presence of hydrogen from water vapor. In all cases, the presence of water vapor increased the amount of HCl formed, but INCONEL was judged less suitable than quartz because INCONEL gave low recovery of organohalogen as HCl.

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FOREWORD

Measurement and monitoring research efforts are designed to anticipate environmental problems, to support regulatory actions by developing an in-depth understanding of the nature and processes that impact health and the ecology, to provide innovative means of monitoring compliance with regulations, and to evaluate the effectiveness of health and environmental protection efforts through the monitoring of long-term trends. The Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, North Carolina, has responsibility for assessment of environmental monitoring technology and systems for air, implementation of agency-wide quality assurance programs for air pollution measurement systems, and supplying technical support to other groups in the Agency including the Office of Air and Radiation, the Office of Toxic Substances, and the Office of Solid Waste.

Permits issued to hazardous waste incinerators allow control of hydrogen chloride emission by placing chlorine limits on the waste feed and by use of acid-gas scrubbers.

This report describes the results of laboratory experiments to develop a method to determine HCl-forming potential through incineration and recovery of organic and inorganic chlorine.

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ABSTRACT

A laboratory method has been developed to provide an estimate of the amount of hydrogen chloride gas that will form during incineration of a waste. The method involves heating of a sample of the waste to 900°C in a tube furnace, removal of particles from the resulting gases by filtration at 250°F (120°C), collection of hydrogen chloride gas in a water-filled impinger, and measurement of the collected HCl as chloride using a standard ion chromatography/conductimetric detection method. Duplicate experimental runs were conducted with quartz and with INCONEL components in the furnace zone of the apparatus. The two materials gave quite different results, which indicates some surface phenomenon may be involved.

Results with quartz components indicated that organochlorine is essentially completely converted to HCl. Very ionic inorganic chlorides (e.g., KCl and NaCl) formed little or no HCl when heated in zero grade air (<3 ppm water and <1 ppm total hydrocarbon) but gave large amounts of HCl (20-80% conversion) if the controlled atmosphere inside the apparatus contained 2.4-5.0% water vapor, which contains hydrogen for HCl formation. Results with less ionic inorganic chloride ($FeCl_3$) and with chlorine in a positive oxidation state (NaClO solution) indicated significant conversion to HCl, especially in the presence of hydrogen from water vapor. In all cases, the presence of water vapor increased the amount of HCl formed, but INCONEL gave low recovery of organohalogen as HCl.

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SECTION 1

INTRODUCTION

Current USEPA regulations for permitted hazardous waste incinerators require analysis of the waste feed for total organochlorine content. At present, no adequate analytical method is known that will accomplish this. Furthermore, a method to measure hydrogen chloride emission potential in waste feed would be preferable since the purpose of the regulations is to control emission of HCl.

The current method assumes that organochlorine is the dominant source of HCl emissions from hazardous waste incinerators. Chlorine-containing organic molecules contain atoms of both elements required to form hydrogen chloride. For this reason, chlorine-containing organic compounds form HCl when burned in air.[1] Without a source of hydrogen, inorganic chlorides do not form HCl when heated to high temperatures in dry air. The result of heating an inorganic chloride to high temperature in the presence of a hydrogen-containing species (e.g., water) apparently has not been investigated in previous work.

The ultimate goal of the work described here is to develop a laboratory method to estimate, from analysis of a waste, the maximum amount of HCl that could form during incineration of that waste, regardless of the chemical environment of chlorine in the waste. The analytical approach chosen for evaluation involved heating a sample of chlorine-containing waste in a tube furnace, filtering particulate chloride from the hot gas stream, and trapping hydrogen chloride (HCl) gas by bubbling the filtered gas through water in an impinger. The collected HCl was measured as chloride (Cl^-) by ion chromatography(IC)/conductimetric analysis of the water solution.

Experimental parameters evaluated included the effect on HCl formation of (1) the bonding environment of chlorine in the waste, (2) the furnace temperature, (3) the presence of water vapor in the controlled atmosphere inside the apparatus, and (4) the composition of the components of the apparatus that actually came into contact with the waste as it

passed through the furnace zone. A total of 35 experimental runs, each consisting of a prerun blank, three to five separate injections of the waste, and a postrun blank, were conducted.

Four types of synthetic wastes were used: (1) waste containing only organochlorine, (2) waste containing only inorganic chloride, (3) waste containing hypochlorite, and (4) waste containing both organochlorine and inorganic chlorides. Two types of real-world wastes were used: (1) an aqueous waste containing an estimated 0.4% organochlorine and (2) an aqueous waste from a bleaching process presumably containing significant amounts of hypochlorite.

Section 2 of this report contains the conclusions drawn from the results of this work. Section 3 contains recommendations for future work. Section 4 describes the laboratory apparatus, experimental run procedures, analytical procedures, the wastes used, and the generation of various test atmospheres. Section 5 contains the results of the evaluation and a discussion of the implications of the results. A bibliography of reference materials cited in an earlier report[1] follows the list of references cited herein. The appendix at the end of the report gives a complete listing of raw laboratory data for all experimental runs.

SECTION 2

CONCLUSIONS

The results of this study have shown that formation of hydrogen chloride from incineration of a waste depends upon (1) the chemical bonding environment of chlorine in the waste, (2) the presence of hydrogen in the furnace zone atmosphere, and (3) the composition of the walls and other surfaces in the furnace zone.

In a quartz tube, organochlorine tends to be completely converted to HCl and does not require an external source of hydrogen. Heating of the organochlorine compound in an INCONEL 600 tube (commercially available from Tube Sales, 9119 Forsythe Park, Charlotte, NC 28241) gave no measurable amount of HCl in the collection impinger. Ionic inorganic chloride is not converted to HCl, in quartz or INCONEL 600, unless a source of hydrogen (e.g., water vapor) is present. Ferric chloride results more closely resemble those obtained with organochlorine than those obtained with very ionic chlorides.

The presence of hydrogen (from water vapor) increased conversion of inorganic chlorine to HCl. This was true with both quartz and INCONEL components in the tube furnace.

SECTION 3

RECOMMENDATIONS

The purpose of this method development activity was to develop a procedure that would allow estimation of the release of HCl during incineration of a hazardous waste feed stock. This project showed that such a method is impractical since the conversion of inorganic chlorine-containing compounds to HCl is incomplete and variable. Accordingly, it is recommended that the Agency estimate the maximum hydrogen chloride concentration either by assuming total conversion of both organic and inorganic chlorides to HCl or by making a direct stack gas measurement.

To measure the acid gas control device efficiency an emission test both before and after the scrubber will be needed, because estimates of the maximum hydrogen chloride emission from feed data may lead to overestimation of scrubber efficiency.

Many additional studies could be performed to better define the parameters affecting the conversion of chlorides to hydrochloric acid. Experiments on pilot and full-scale incinerators would be interesting and potentially useful to regulators as well as those regulated. It is currently thought, however, that the conversion process is probably sensitive to enough parameters that accurate quantitative prediction by any test method is unlikely.

SECTION 4

EXPERIMENTAL PROCEDURES

The following sections describe (1) the laboratory apparatus, (2) the procedures for injecting waste samples, and (3) the collection and analysis of HCl samples. Several initial runs were conducted with the assembled apparatus to determine optimum sample size and heat-tracing requirements. Wastes containing organochlorine, assumed converted completely to HCl during combustion, were used to monitor accuracy (percent recovery) as improvements were made in the apparatus and as the chlorine content of the waste and the injection volume were optimized.

APPARATUS

The laboratory apparatus used for the study is shown schematically in Figure 1. The components included (1) an injection assembly, (2) a furnace zone (tube furnace), (3) a heated filter zone (to remove particulate matter), and (4) hydrogen chloride sample collectors.

Injection Assembly

The injection assembly consisted of a moveable boat mechanism sealed inside a glass housing located immediately upstream from the furnace zone. The design of this assembly allowed for injection of a waste sample into a completely sealed system exposed only to the controlled atmosphere inside the apparatus.

The boat mechanism was made from either quartz or INCONEL components to match the composition of the furnace tube. The mechanism consisted of a rod with a 32-mm long sample boat or reservoir mounted on one end and a piece of magnetic material attached to the other end.

The boat mechanism was housed in a 0.5-in. O.D. glass tube equipped at one end with a 28/15 ball joint, which was connected to the furnace tube, and at the opposite end with a #7 ACE-Thred connector (ACE Glass Inc., 1430 Northwest Boulevard, Vineland, New Jersey 08360) to which the air supply line was attached. A 4-mm I.D. tube stub was mounted on the top side of the housing approximately 1.5 in. from the ball joint. This

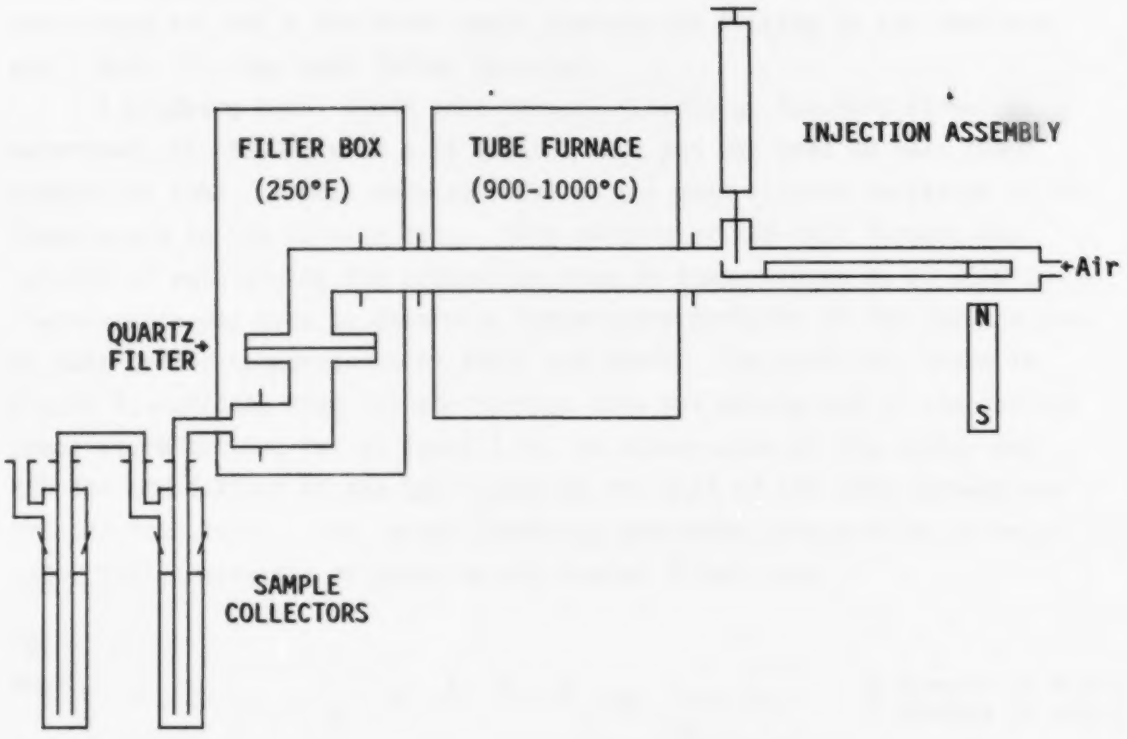

Figure 1. Laboratory apparatus used in the study.

tube was fitted with a septum and provided a means for introducing liquid samples from a syringe directly into the boat inside a sealed system.

A hand-held magnet (outside the glass tube) was used to push the boat into the furnace zone and to withdraw it after volatilization and/or incineration of the sample.

Furnace Zone

The furnace zone was inside a quartz or INCONEL combustion tube that was heated in a tube furnace. Waste samples were volatilized and/or thermally oxidized in the furnace zone. Chlorine, if present in the waste, then combined with hydrogen to form hydrogen chloride.

Specifically, two types of combustion tube used were: (1) a 14-in. long, 0.5-in. I.D. quartz tube equipped with a 28/15 quartz socket joint on each end and (2) a 14-in. long, 0.5-in. O.D. INCONEL 600 (76% nickel, 15.5%

chromium, and 8.0% iron) tube with an INCONEL compression fitting on the downstream end and a stainless steel compression fitting on the upstream end. Both fittings used Teflon ferrules.

A Lindberg Model 55035 tube furnace (Lindberg, 304 Hart Street, Watertown, WI 53094) with a 13 1/2-in. tube bed was used to heat the combustion tube. A heat selector dial on the oven allowed variation of the temperature in the furnace zone. This particular 120-volt furnace was capable of maintaining the combustion tube at temperatures up to 1066°C. A thermocouple was used to determine temperature profiles of the furnace zone at tube-center temperatures of 400°C and 900°C. The profiles, shown in Figure 2, indicate that (1) the furnace zone was maintained at the desired temperature setting for at least 1 in. on either side of the center and (2) the temperature of the gas stream at the exit of the tube furnace was greater than 100°C. The latter condition prevented condensation of water vapor during transfer of gases to the heated filter zone.

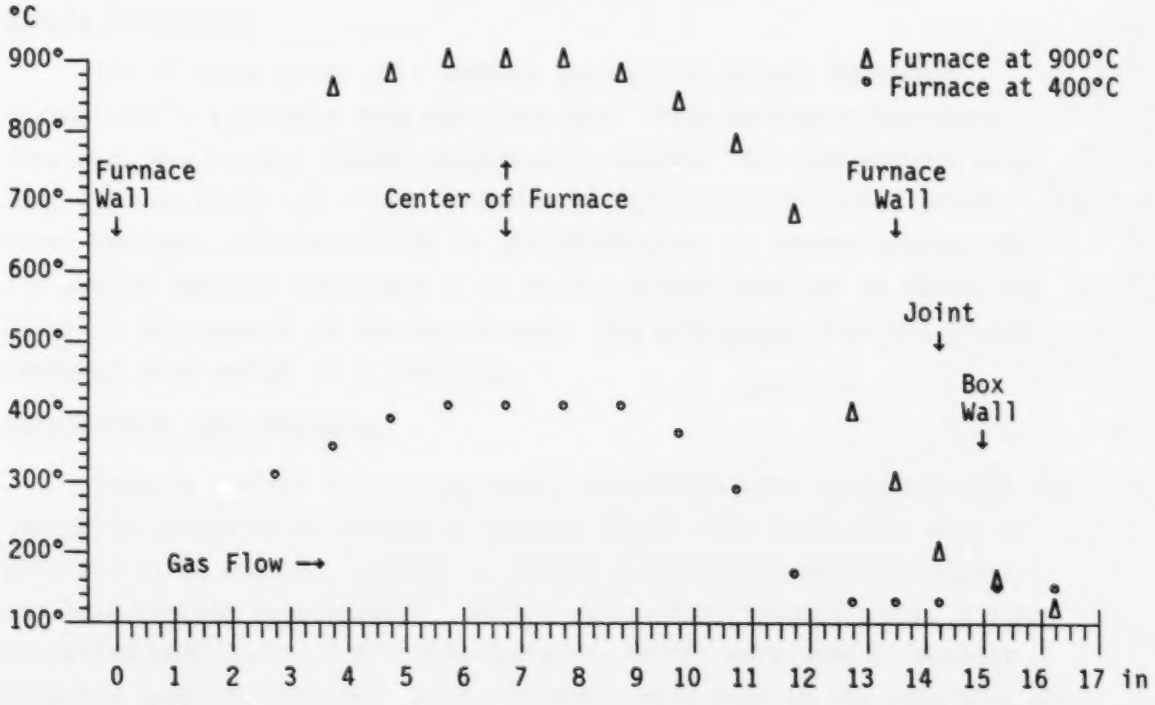

Figure 2. Temperature of gas plotted against distance from furnace inlet.

Heated Filter Zone

Connectors constructed from 0.5-in. O.D. glass tubing were used to connect the furnace tube to a filter apparatus and the filter apparatus to the sample collector. The filter apparatus (commercially available from Nutech Corporation, 2806 Cheek Road, Durham, NC 27704) consisted of a quartz-fiber filter supported by a perforated Teflon disk and was used to remove particulate material from gases products. The filter apparatus was similar to the one used in USEPA's Modified Method 5 Sampling Train.[2] The 4-in. filter holder was made of borosilicate glass and was equipped with 28/15 socket joints at the inlet and outlet. The filter was prepared from 8x10-in. sheets of quartz filter paper (commercially available from Pallflex Inc., 125 Kennedy Drive, Putnam, CT 06260, Model No. 2500 QAOT). The entire filter apparatus and associated connectors were housed in an insulated box and maintained at a temperature of 250°F (120°C) to prevent condensation of gaseous material.

Sample Collectors

The filtered gases were bubbled through two midget impingers (commercially available from ACE Glass Inc., 1430 Northwest Boulevard, Vineland, New Jersey 08360) connected in series. All connections were made through glass connectors fitted with 12/5 ball-and-socket joints. The first impinger contained 15 mL of deionized water to remove gaseous HCl. The second impinger contained 15 mL of 0.1 N NaOH solution to remove any chlorine gas present in the gas stream. The exit gases from the second impinger were vented to a fume hood.

EXPERIMENTAL RUN PROCEDURE

Several initial runs using quartz components were conducted with the assembled apparatus to determine optimum sample size (actually, mass of chlorine which must be injected to obtain a reasonable percent recovery) and heat-tracing requirements. Wastes containing organochlorine, assumed converted completely to HCl when heated to 900°C, were used to monitor accuracy (percent recovery) as improvements were made in the apparatus and as the chlorine content of the waste and the injection volume were adjusted to achieve acceptable results.

Each experimental run consisted of (1) a single injection of a blank (referred to as the prerun blank), (2) three to five separate injections of

the waste, and (3) a second injection of a blank (referred to as the postrun blank). The blanks were made up of the same matrix (ethanol and/or water) as the sample but contained no chlorine-containing species. The prerun and postrun blanks were used to monitor background concentrations of HCl. Each injection (waste or blank) generated a single liquid sample (collected in the first impinger) that was subsequently analyzed for chloride by IC with conductimetric detection.

The procedure used for each injection (waste or blank) into the laboratory apparatus consisted of eight steps:

1. The midget impingers were attached to the gas outlet just downstream from the heated filter zone.
2. The air supply valve was turned on.
3. The apparatus was checked for leaks.
4. A known volume of sample (waste or blank) was injected into the boat with a syringe.
5. The boat was moved into the furnace zone by means of the hand-held magnet.
6. After 15 min, the impingers were disconnected.
7. After an additional 15 min, the boat was removed from the furnace zone.
8. After 30 more min (60 min total from Step 5), the air supply valve was turned off.

This procedure was repeated for each injection of the run. All liquid samples from the first impinger were analyzed for chloride content.

SAMPLE PREPARATION AND ANALYSIS

After volatilization and/or incineration of an injection of material (waste or blank), the deionized water in the first midget impinger was transferred quantitatively to a 25-mL volumetric flask and diluted to volume with deionized water. The solution was then analyzed for chloride on a Dionex Model 14 ion chromatograph (Dionex Corporation, 1228-T Titan Way, Sunnyvale, CA 94086) with conductimetric detection. A quaternary ammonium resin separator column and an anion fiber (acid form) suppressor column were used for the separation. A bicarbonate/carbonate buffer solution was used as the eluent. Solutions to be analyzed were diluted, if

necessary, to obtain a Cl^- concentration in the range of 0.06 to 15 ppm, the optimum working range for the measurement method. The conductivity meter had a detection limit of 0.01 ppm Cl^-.

WASTES STUDIED

Synthetic Wastes

Some properties of the chemical compounds used in the study are given in Table 1. The compounds selected for the final set of synthetic wastes were methylene chloride, an organohalogen compound; ferric chloride, a predominantly molecular inorganic compound; and sodium chloride and potassium chloride, two very ionic inorganic compounds. In addition, a

TABLE 1. PROPERTIES OF COMPOUNDS USED IN THE LABORATORY STUDY[3]

Compound		Melting Point (°C)	Boiling Point[a] (°C)	Solubility[b]	
Class/Name	Formula			Water	Alcohol
Inorganic Compounds:					
sodium chloride	NaCl	801	1413	s	ss
potassium chloride	KCl	770	s 1500	s	ss
iron(III) chloride	$FeCl_3$	306	d 315	s	vs
sodium hypochlorite	NaClO (aque.)			s	
Organic Compounds:					
methylene chloride	CH_2Cl_2	-95	40	δ	∞
p-dichlorobenzene	$C_6H_4Cl_2$	53	174	i	∞
Solvents:					
ethanol	CH_3CH_2OH	-117	79	∞	-
water	H_2O	0	100	-	∞

[a]Abbreviations used with boiling point: d = decomposes, s = sublimes.

[b]Abbreviations used for solubility:

i = insoluble
δ = partially soluble
ss = slightly soluble
s = soluble
vs = very soluble
∞ = infinitely soluble

solution of sodium hypochlorite was used as a synthetic waste containing chlorine in a positive oxidation state. Table 2 gives the composition and chlorine concentration of the wastes.

Real-World Wastes

Two real-world wastes were used in the study. The first was an aqueous waste containing a large amount of organochlorine. Waste samples taken just before and just after the one used in this study had been analyzed by gas chromatography/mass spectrometry when they were collected in 1986. Estimates of the concentrations of chlorine-containing compounds were computed by averaging the two measured values for each compound. The results are shown in Table 3. The second real-world waste was also aqueous and contained large amounts of inorganic chlorine.

Blanks

For the purposes of this evaluation, blank values were determined by injecting pure ethanol or a water-ethanol mixture, as appropriate, into the apparatus and measuring the background Cl^- concentration in the water-impinger solution. Blanks were the first and last injections of each experimental run. The blank value was computed as the average of the chloride concentrations from the prerun and postrun blank injections.

TABLE 2. SYNTHETIC WASTES

Synthetic Waste	Composition	Chlorine Concentration
9.5% $NaCl/H_2O$	105 mg NaCl per mL of H_2O	5.8%
11.8% KCl/H_2O	134 mg KCl per mL of H_2O	5.6%
6.6% CH_2Cl_2/EtOH	56.1 mg CH_2Cl_2 per mL of EtOH	5.5%
6.2% $FeCl_3/H_2O$	66.5* mg $FeCl_3$ per mL of H_2O	4.1%*
4-6% $NaClO/H_2O$	Unknown	

*Calculated from chloride concentration measured by ion chromatography.

TABLE 3. COMPOSITION OF REAL-WORLD WASTE (ORGANIC)

Chlorine-Containing Compounds*	Est. Conc. (ppm)	Chlorine Content of Waste
1,2-Dichloroethane	5,300	0.4%
Chloroform	240	
1,1-Dichloroethane	11	
Chloroethane	7	
1,1,2-Trichloroethane	6	
Vinyl Chloride	6	
1,1-Dichloroethene	3	
Trichloroethene	3	

*With concentration >1 ppm in the aqueous waste

TEST ATMOSPHERES

Four different atmospheres were investigated: (1) 100% zero grade air, (2) zero air containing 0.5% propane, (3) zero air containing 2.4% water vapor, and (4) zero air containing 5.0% water vapor. The last three atmospheres were investigated to determine if the presence of a hydrogen-containing species would affect the recovery of inorganic chlorine as HCl.

The propane-air atmosphere was generated by introducing a small flow of a known concentration of a propane in nitrogen mixture into 100% zero grade air. The resulting mixture contained 0.5% propane.

The water vapor-air atmospheres were generated by bubbling 100% zero grade air through a heated reservoir of deionized water. The temperature of the water determined the amount of water vapor in the resulting humidified air. The moisture content of the airstream was calculated, as shown by the equation below, from the ratio of vapor pressure of water at the temperature of the reservoir to atmospheric pressure.

$$V_{\%} = \frac{P_v}{P_a}(100)$$

$V_{\%}$ = Percent water (by volume)

P_v = Vapor pressure of water at temperature of flask

P_a = Atmospheric pressure

An airflow of 200 mL/min, introduced through a 0.25-in. O.D. Teflon tube to the #7 ACE-Thred joint on the upstream end of the injection assembly, was used to sweep material through the furnace tube and sampling

train. This flow rate gave a residence time of 3-4 sec in the hottest part of the tube. At the 900°C setting, residence time in the region heated above 700°C was 8-10 sec.

SECTION 5

RESULTS AND DISCUSSION

A furnace tube and boat mechanism made of quartz were used for all preliminary runs. The controlled atmosphere inside the apparatus was 100% zero grade air and the temperature in the furnace zone was 900°C. Results of those runs appeared straightforward: Organohalogen was converted to HCl; inorganic chloride was not. Runs at 1000°C gave similar results.

Because the purpose of the proposed method was to estimate HCl formation in a waste incinerator, an effort was then made to make conditions in the laboratory apparatus more closely resemble those in an actual incinerator. One major difference was the absence of hydrogen during heating of inorganic wastes in the laboratory apparatus. In laboratory runs, inorganic chloride was dissolved in water, and a small sample of the resulting solution was injected into the boat, along with an equal volume of ethanol. As the boat was moved into the furnace zone, the water and ethanol evaporated, leaving the hot inorganic chloride in an atmosphere containing no hydrogen with which to combine (zero grade air contains less than 3 ppm H_2O). In a real incinerator, excess hydrogen is usually available either from waste feed or supplementary fuel.

A gas-mixing system was then added to the laboratory apparatus. It allowed the preparation of an atmosphere containing a small amount of propane (0.5%) in zero grade air. Under the new conditions, 30-50% of inorganic chloride was converted to HCl.

Other hydrogen sources were then considered because of the safety hazards associated with handling propane. Water vapor was the obvious choice. Approximately 40% of inorganic chloride heated in an atmosphere containing water vapor was recovered as HCl. The presence of large amounts of HCl in the heated and filtered gases was confirmed by gas-filter correlation infrared spectroscopy (HCl analyzer). Likewise, IC analysis of an impinger solution collected following an injection of sodium chloride indicated 52.7% recovery of Cl^- as HCl, whereas analysis of the same solution by inductively coupled argon plasma indicated only 3.8% recovery of Na^+.

Table 4 summarizes recovery of chloride (from NaCl) as HCl after heating at 900°C and at 1000°C in (1) 100% zero grade air, (2) zero grade air containing 0.5% propane, and (3) zero grade air containing 2.4% water vapor. The concentrations of propane and water vapor above gave approximately the same concentration of hydrogen in the controlled atmosphere inside the apparatus and gave very similar recoveries of chloride as HCl. Increasing the water vapor concentration to 5.0% had no appreciable effect on recovery of chloride as HCl. Water vapor (2.4%) was used for all subsequent runs requiring a source of hydrogen.

Addition of water vapor to the zero grade air led to problems with degradation of quartz components. The tube and boat took on a frosted appearance, and a white crust built up on the inside of the tube. The grainy material thus formed was insoluble in water and was determined to be amorphous by polarized light microscopy. Because comparison runs (Table 4) indicated no significant difference in HCl formation at 900°C and 1000°C, remaining runs were conducted at 900°C to reduce the degradation of quartz components.

The frosted appearance of the boat was a common observation for all inorganic chloride runs except those involving ferric chloride. The boat was a brownish-red at the end of the ferric chloride runs presumably because of the presence of iron in the degraded quartz. This provides additional evidence that metal cations may remain, perhaps as silicates, on the walls of the tube and boat following conversion of chloride to HCl.

TABLE 4. RECOVERY FROM SODIUM CHLORIDE AT 900°C AND 1000°C

Zero Air Containing		Mean Recovery of Cl^- as HCl	
Propane	Water	900°C	1000°C
no	no	0.6%	5.1%
0.5%	no	30.7%	48.5%
no	2.4%	38.5%	38.5%

Degradation of quartz components and increased conversion of inorganic chloride to HCl occurred simultaneously. It was not obvious whether the two phenomena were related or not, or, if they were related, which was the driving factor. A furnace tube and boat made of INCONEL 600 (76.0% nickel, 15.5% chromium, and 8.0% iron) were used to determine if HCl formation was affected by the chemical composition of surfaces in the furnace zone. Consequently, experimental runs with synthetic and real-world wastes were repeated with INCONEL components.

The INCONEL tube withstood the 900°C temperatures of the furnace without sagging. The interior of the tube became discolored after several runs. The surface of the INCONEL boat mechanism slowly deteriorated during the study. The boat eventually became pitted and cracked, and material resembling iron filings collected in the tube. This material was attracted to a magnet, the INCONEL components were not.

Table 5 gives the results of all experimental runs at 900°C with quartz components and with INCONEL components, with water vapor present and without. All laboratory data are given in the Appendix and may be referenced by the run number given in Table 5. The following observations may be made about the results in Table 5.

1. Comparison of results with and without a source of hydrogen (water vapor) in the controlled atmosphere inside the apparatus:

   a. Predominantly covalent chlorine-containing compounds (CH_2Cl_2 and $FeCl_3$) gave a higher percent conversion of chlorine to HCl when water vapor was present in every experimental run except one. The exception was CH_2Cl_2 with quartz components.

   b. Predominantly ionic chlorine-containing compounds (NaCl and KCl) gave a higher percent conversion of chlorine to HCl when water vapor was present in every experimental run.

2. Comparison of results with quartz components and with INCONEL components:

   a. Predominantly covalent chlorine-containing compounds (CH_2Cl_2 and $FeCl_3$) gave a higher percent conversion of chlorine to HCl with quartz components.

   b. Predominantly ionic chlorine-containing compounds (NaCl and KCl) gave a higher percent conversion of chlorine to HCl with INCONEL components.

3. Comparison of prerun and postrun blank concentrations:

   a. For 6 of the 15 quartz tube runs at 900°C and 10 of the 17 INCONEL runs, the HCl concentration of the blank at the end of the run was at least twice the concentration of the blank at the beginning of the run.

   b. For 1 quartz tube run and 6 INCONEL runs, the HCl concentration of the blank at the end of the run was lower than the concentration of the blank at the beginning of the run.

No statistical analysis is presented here because of the limited quantity of data.

TABLE 5. RECOVERY OF CHLORINE AS HCl AT 900°C

Composition of Sample	Mass Cl Injected (mg)	Water Vapor Conc.	Quartz			INCONEL		
			Run No.	Mass Cl Recovered (mg)	Percent Recovery (%)	Run No.	Mass Cl Recovered (mg)	Percent Recovery (%)
6.6% CH_2Cl_2/EtOH	0.234	0%	1	0.242	103. %	19	0.0060	2.6 %
						20	0.0023	1.0 %
		2.4%	2	0.1755	75.0 %	21	0.0833	35.6 %
						22	0.0949	40.6 %
						23	0.1501	64.1 %
9.5% NaCl/H_2O	0.319	0%	3	0.0063	2.0 %	24	0.0160	5.0 %
			4	0.0018	0.55%			
		2.4%	8	0.1227	38.5 %	25	0.1447	45.4 %
						26	0.2649	83.1 %
						27	0.266	83.4 %
11.8% KCl/H_2O	0.319	0%	11	0.0018	0.56%	29	0.0059	1.8 %
		2.4%	12	0.0755	23.7 %	30	0.0593	18.6 %
6.2% $FeCl_3$/H_2O	0.436	0%	13	0.3349	76.8 %	31	0.0226	5.2 %
		2.4%	14	0.4044	92.8 %	32	0.2969	68.1 %
4-6% NaOCl Soln.	Unknown	2.4%	15	0.1442		33	0.2934	
Real-World Waste (Organic)	Unknown	0%	16	0.1810				
		2.4%				34	0.3191	
Real-World Waste (Inorganic)	Unknown	2.4%	18	0.0590		35	0.0840	

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APPENDIX A

LABORATORY DATA

Table A-1 includes raw laboratory data for all experimental runs. The runs are arranged and numbered according to the following priority sequence:

Tube/Boat Material
Composition of Sample
Water Vapor Concentration
Temperature

Within each run, injections are arranged in the sequence:

Prerun Blank
Waste Sample Injections
Postrun Blank

The blank value used to compute the adjusted concentration for each waste sample injection is the average of the prerun and postrun blank values.

Runs with sodium chloride in quartz at 900°C and 1000°C, with and without propane and water vapor, are summarized in Table 4 in the text. All runs at 900°C in quartz and in INCONEL, with and without water vapor, are summarized in Table 5.

TABLE A-1. LABORATORY DATA

RUN	SAMPLE COLLECTION							ANALYSIS BY IC			RECOVERY OF Cl AS HCl		
								Cl^- Concentration			Cl^- Recovered		
No.	Tube/Boat Material and Temp.	Water Vapor Conc.	Composition of Sample Injected	Vol. Inj. (μL)	Mass Cl Inj. (mg)	Vol. Imp. Solution (L)	Inj. No.	Meas. (mg/L)	Blank (mg/L)	Adj. (mg/L)	Mass (mg)	Mean(mg) [%RSD]	Percent Recov.
1	QUARTZ 900°C	0%	Blank (EtOH)	5		0.025	1	0.085					
			6.6% CH_2Cl_2/EtOH	5	0.234	0.025	2	9.31	0.084	9.23	0.231	0.242 [3.8%]	103%
							3	10.02	0.084	9.94	0.248		
							4	9.92	0.084	9.84	0.246		
			Blank (EtOH)	5		0.025	5	0.083					
2	QUARTZ 900°C	2.4%	Blank (EtOH)	5		0.025	1	0.122					
			6.6% CH_2Cl_2/EtOH	5	0.234	0.025	2	7.057	0.131	6.926	0.1732	0.1755 [3.0%]	75.0%
							3	7.236	0.131	7.105	0.1776		
							4	6.860	0.131	6.729	0.1682		
							5	7.176	0.131	7.045	0.1761		
							6	7.421	0.131	7.290	0.1823		
			Blank (EtOH)	5		0.025	7	0.140					

(continued)

TABLE A-1. (Continued)

RUN	SAMPLE COLLECTION							ANALYSIS BY IC			RECOVERY OF Cl AS HCl		
								Cl^- Concentration			Cl^- Recovered		
No.	Tube/Boat Material and Temp.	Water Vapor Conc.	Composition of Sample Injected	Vol. Inj. (μL)	Mass Cl Inj. (mg)	Vol. Imp. Solution (L)	Inj. No.	Meas. (mg/L)	Blank (mg/L)	Adj. (mg/L)	Mass (mg)	Mean(mg) [%RSD]	Percent Recov.
3	QUARTZ 900°C	0%	Blank (H_2O,EtOH)	5,5		0.025	1	0.117					
			9.5% NaCl/H_2O EtOH	5 5	0.319	0.025	2	0.135	0.117	0.018	0.0005	0.0063 [100%]	2.0%
							3	0.321	0.117	0.204	0.0051		
							4	0.654	0.117	0.537	0.0134		
			Blank (H_2O,EtOH)	5,5		0.025	5	Lost					
4	QUARTZ 900°C	0%	Blank (H_2O,EtOH)	5,5		0.025	1	0.210					
			9.5% NaCl/H_2O EtOH	5 5	0.319	0.025	2	0.265	0.250	0.015	0.0004	0.0018 [79%]	0.55%
							3	0.318	0.250	0.068	0.0017		
							4	0.378	0.250	0.128	0.0032		
			Blank (H_2O,EtOH)	5,5		0.025	5	0.289					
5	QUARTZ 1,000°C	0%	Blank (H_2O,EtOH)	5,5		0.025	1	0.090					
			9.5% NaCl/H_2O EtOH	5 5	0.319	0.025	2	1.149	0.473	0.676	0.0169	0.0157 [41.5%]	4.9%
							3	1.337	0.473	0.864	0.0216		
							4	0.819	0.473	0.346	0.0087		
			Blank (H_2O,EtOH)	5,5		0.025	5	0.855					

(continued)

TABLE A-1. (Continued)

RUN	SAMPLE COLLECTION							ANALYSIS BY IC			RECOVERY OF Cl AS HCl		
								Cl^- Concentration			Cl^- Recovered		
No.	Tube/Boat Material and Temp.	Water Vapor Conc.	Composition of Sample Injected	Vol. Inj. (μL)	Mass Cl Inj. (mg)	Vol. Imp. Solution (L)	Inj. No.	Meas. (mg/L)	Blank (mg/L)	Adj. (mg/L)	Mass (mg)	Mean(mg) [%RSD]	Percent Recov.
6	QUARTZ 900°C	0% [0.5% C_3H_8]	Blank (H_2O,EtOH)	5,5		0.025	1	0.883					
			9.5% NaCl/H_2O EtOH	5 5	0.319	0.025	2	6.012	1.077	4.935	0.1234	0.0978 [23.4%]	30.6%
							3	4.747	1.077	3.670	0.0918		
							4	4.217	1.077	3.140	0.0785		
			Blank (H_2O,EtOH)	5,5		0.025	5	1.271					
7	QUARTZ 1,000°C	0% [0.5% C_3H_8]	Blank (H_2O,EtOH)	5,5		0.025	1	0.148					
			9.5% NaCl/H_2O EtOH	5 5	0.319	0.025	2	7.448	0.592	6.856	0.1714	0.1546 [12.8%]	48.5%
							3	6.983	0.592	6.391	0.1598		
							4	5.898	0.592	5.307	0.1327		
			Blank (H_2O,EtOH)	5,5		0.025	5	1.036					
8	QUARTZ 900°C	2.4%	Blank (H_2O,EtOH)	5,5		0.025	1	0.086					
			9.5% NaCl/H_2O EtOH	5 5	0.319	0.025	2	6.802	0.625	6.177	0.1544	0.1227 [24.5%]	38.5%
							3	5.387	0.625	4.762	0.1191		
							4	4.410	0.625	3.785	0.0946		
			Blank (H_2O,EtOH)	5,5		0.025	5	1.164					

(continued)

TABLE A-1. (Continued)

RUN	SAMPLE COLLECTION							ANALYSIS BY IC			RECOVERY OF Cl AS HCl		
								Cl^- Concentration			Cl^- Recovered		
No.	Tube/Boat Material and Temp.	Water Vapor Conc.	Composition of Sample Injected	Vol. Inj. (μL)	Mass Cl Inj. (mg)	Vol. Imp. Solution (L)	Inj. No.	Meas. (mg/L)	Blank (mg/L)	Adj. (mg/L)	Mass (mg)	Mean(mg) [%RSD]	Percent Recov.
9	QUARTZ 1,000°C	2.4%	Blank (H_2O,EtOH)	5,5		0.025	1	0.183					
			9.5% NaCl/H_2O EtOH	5 5	0.319	0.025	2	7.704	0.306	7.398	0.1850	0.1512 [19.3%]	47.4%
							3	5.691	0.306	5.385	0.1346		
							4	5.670	0.306	5.364	0.1341		
			Blank (H_2O,EtOH)	5,5		0.025	5	0.428					
10	QUARTZ 900°C	5.0%	Blank (H_2O,EtOH)	5,5		0.025	1	0.37					
			9.5% NaCl/H_2O EtOH	5 5	0.319	0.025	2	6.16	0.40	5.76	0.144	0.134 [7.1%]	42.0%
							3	5.76	0.40	5.36	0.134		
							4	5.40	0.40	5.00	0.125		
			Blank (H_2O,EtOH)	5,5		0.025	5	0.42					

(continued)

TABLE A-1. (Continued)

RUN	SAMPLE COLLECTION							ANALYSIS BY IC			RECOVERY OF Cl AS HCl		
								Cl^- Concentration			Cl^- Recovered		
No.	Tube/Boat Material and Temp.	Water Vapor Conc.	Composition of Sample Injected	Vol. Inj. (μL)	Mass Cl Inj. (mg)	Vol. Imp. Solution (L)	Inj. No.	Meas. (mg/L)	Blank (mg/L)	Adj. (mg/L)	Mass (mg)	Mean(mg) [%RSD]	Percent Recov.
11	QUARTZ 900°C	0%	Blank (H_2O,EtOH)	5,5		0.025	1	0.080					
			11.8% KCl/H_2O EtOH	5 5	0.319	0.025	2	0.197	0.140	0.057	0.0014	0.0018 [25.2%]	0.56%
							3	0.201	0.140	0.061	0.0015		
							4	0.204	0.140	0.064	0.0016		
							5	0.221	0.140	0.081	0.0020		
							6	0.239	0.140	0.099	0.0025		
			Blank (H_2O,EtOH)	5,5		0.025	7	0.199					
12	QUARTZ 900°C	2.4%	Blank (H_2O,EtOH)	5,5		0.025	1	0.064					
			11.8% KCl/H_2O EtOH	5 5	0.319	0.025	2	3.602	0.198	3.404	0.0851	0.0755 [30.7%]	23.7%
							3	4.196	0.198	3.998	0.1000		
							4	3.542	0.198	3.344	0.0836		
							5	3.007	0.198	2.809	0.0702		
							6	1.743	0.198	1.545	0.0386		
			Blank (H_2O,EtOH)	5,5		0.025	7	0.332					

(continued)

TABLE A-1. (Continued)

RUN	SAMPLE COLLECTION							ANALYSIS BY IC			RECOVERY OF Cl AS HCl		
								Cl^- Concentration			Cl^- Recovered		
No.	Tube/Boat Material and Temp.	Water Vapor Conc.	Composition of Sample Injected	Vol. Inj. (μL)	Mass Cl Inj. (mg)	Vol. Imp. Solution (L)	Inj. No.	Meas. (mg/L)	Blank (mg/L)	Adj. (mg/L)	Mass (mg)	Mean(mg) [%RSD]	Percent Recov.
13	QUARTZ 900°C	0%	Blank (H_2O,EtOH)	10,5		0.025	1	0.186					
			6.2% $FeCl_3/H_2O$ EtOH	10 5	0.436	0.025	2	11.83	0.221	11.61	0.2901	0.3349 [8.6%]	76.8%
							3	13.25	0.221	13.03	0.3257		
							4	14.21	0.221	13.99	0.3497		
							5	14.84	0.221	14.62	0.3655		
							6	13.96	0.221	13.74	0.3435		
			Blank (H_2O,EtOH)	10,5		0.025	7	0.256					
14	QUARTZ 900°C	2.4%	Blank (H_2O,EtOH)	10,5		0.025	1	0.147					
			6.2% $FeCl_3/H_2O$ EtOH	10 5	0.436	0.025	2	15.57	0.215	15.35	0.3838	0.4044 [3.7%]	92.8%
							3	15.91	0.215	15.91	0.3978		
							4	16.95	0.215	16.95	0.4238		
							5	16.29	0.215	16.29	0.4073		
							6	16.38	0.215	16.38	0.4094		
			Blank (H_2O,EtOH)	10,5		0.025	7	0.282					

(continued)

TABLE A-1. (Continued)

RUN	SAMPLE COLLECTION							ANALYSIS BY IC			RECOVERY OF Cl AS HCl		
								Cl^- Concentration			Cl^- Recovered		
No.	Tube/Boat Material and Temp.	Water Vapor Conc.	Composition of Sample Injected	Vol. Inj. (μL)	Mass Cl Inj. (mg)	Vol. Imp. Solution (L)	Inj. No.	Meas. (mg/L)	Blank (mg/L)	Adj. (mg/L)	Mass (mg)	Mean(mg) [%RSD]	Percent Recov.
15	QUARTZ 900°C	2.4%	Blank (H_2O,EtOH)	5,5		0.025	1	0.263					
			4-6% NaOCl Soln. EtOH	5 5	Unknown	0.025	2	7.692	0.359	7.333	0.1833	0.1442 [21.7%]	
							3	6.792	0.359	6.436	0.1609		
							4	6.439	0.359	6.080	0.1520		
							5	4.743	0.359	4.384	0.1096		
							6	4.964	0.359	4.605	0.1151		
			Blank (H_2O,EtOH)	5,5		0.025	7	0.454					
16	QUARTZ 900°C	0%	Blank (H_2O,EtOH)	40, 10		0.025	1	0.192					
			Organic Real World Waste	50	Unknown	0.025	2	6.638	0.714	5.924	0.1481	0.1810 [15.7%]	
							3	8.585	0.714	7.871	0.1968		
							4	8.637	0.714	7.923	0.1981		
			Blank (H_2O,EtOH)	40, 10		0.025	5	1.236					

(continued)

TABLE A-1. (Continued)

RUN	SAMPLE COLLECTION							ANALYSIS BY IC			RECOVERY OF Cl AS HCl		
								Cl⁻ Concentration			Cl⁻ Recovered		
No.	Tube/Boat Material and Temp.	Water Vapor Conc.	Composition of Sample Injected	Vol. Inj. (μL)	Mass Cl Inj. (mg)	Vol. Imp. Solution (L)	Inj. No.	Meas. (mg/L)	Blank (mg/L)	Adj. (mg/L)	Mass (mg)	Mean(mg) [%RSD]	Percent Recov.
17	QUARTZ 900°C	0%	Blank (H_2O,EtOH)	40, 10		0.025	1	0.175					
			Organic Real World Waste Spike (5.7% CH_2Cl_2 /EtOH)	50	Unknown	0.025	2	14.28	0.674	13.61	0.3403	0.3603 [5.5%]	[89.7% of Spike]
				5	0.200		3	15.85	0.674	15.18	0.3795		
							4	15.12	0.674	14.45	0.3613		
			Blank (H_2O,EtOH)	40, 10		0.025	5	1.173					
18	QUARTZ 900°C	2.4%	Blank (H_2O,EtOH)	5,5		0.025	1	0.143					
			Inorganic Real-World Waste EtOH	5		0.025	2	3.003	0.324	2.679	0.0670	0.0590 [17.6%]	
				5			3	3.010	0.324	2.686	0.0672		
							4	2.934	0.324	2.610	0.0653		
							5	2.256	0.324	1.932	0.0483		
							6	2.202	0.324	1.878	0.0470		
			Blank (H_2O,EtOH)	5,5		0.025	7	0.305					

TABLE A-1. (Continued)

RUN	SAMPLE COLLECTION							ANALYSIS BY IC			RECOVERY OF Cl AS HCl		
								Cl^- Concentration			Cl^- Recovered		
No.	Tube/Boat Material and Temp.	Water Vapor Conc.	Composition of Sample Injected	Vol. Inj. (μL)	Mass Cl Inj. (mg)	Vol. Imp. Solution (L)	Inj. No.	Meas. (mg/L)	Blank (mg/L)	Adj. (mg/L)	Mass (mg)	Mean(mg) [%RSD]	Percent Recov.
19	INCONEL 900°C	0%	Blank (EtOH)	5		0.025	1	0.446					
			6.6% CH_2Cl_2/EtOH	5	0.234	0.025	2	0.590	0.748	0.000	0.0000	0.0060 [120%]	2.6%
							3	0.837	0.748	0.089	0.0022		
							4	0.686	0.748	0.000	0.0000		
							5	1.233	0.748	0.485	0.0121		
							6	1.376	0.748	0.628	0.0157		
			Blank (EtOH)	5		0.025	7	1.050					
20	INCONEL 900°C	0%	Blank (EtOH)	5		0.025	1	0.240					
			6.6% CH_2Cl_2/EtOH	5	0.234	0.025	2	0.319	0.529	0.000	0.0000	0.0023 [140%]	1.0%
							3	0.422	0.529	0.000	0.0000		
							4	0.810	0.529	0.281	0.0070		
							5	0.459	0.529	0.000	0.0000		
							6	0.715	0.529	0.186	0.0047		
			Blank (EtOH)	5		0.025	7	0.818					

(continued)

TABLE A-1. (Continued)

RUN	SAMPLE COLLECTION							ANALYSIS BY IC			RECOVERY OF Cl AS HCl		
								Cl^- Concentration			Cl^- Recovered		
No.	Tube/Boat Material and Temp.	Water Vapor Conc.	Composition of Sample Injected	Vol. Inj. (μL)	Mass Cl Inj. (mg)	Vol. Imp. Solution (L)	Inj. No.	Meas. (mg/L)	Blank (mg/L)	Adj. (mg/L)	Mass (mg)	Mean (mg) [%RSD]	Percent Recov.
21	INCONEL 900°C	2.4%	Blank (EtOH)	5		0.025	1	0.898					
			6.6% CH_2Cl_2/EtOH	5	0.234	0.025	2	4.579	0.817	3.762	0.0941	0.0833 [12.6%]	35.6%
							3	4.308	0.817	3.491	0.0873		
							4	3.447	0.817	2.630	0.0658		
							5	4.177	0.817	3.360	0.0840		
							6	4.224	0.817	3.407	0.0852		
			Blank (EtOH)	5		0.025	7	0.736					
22	INCONEL 900°C	2.4%	Blank (EtOH)	5		0.025	1	1.417					
			6.6% CH_2Cl_2/EtOH	5	0.234	0.025	2	3.681	0.944	2.737	0.0684	0.0949 [18.6%]	40.6%
							3	4.617	0.944	3.673	0.0918		
							4	4.654	0.944	3.710	0.0928		
							5	5.225	0.944	4.281	0.1070		
							6	5.525	0.944	4.581	0.1145		
			Blank (EtOH)	5		0.025	7	0.470					

(continued)

TABLE A-1. (Continued)

RUN	SAMPLE COLLECTION							ANALYSIS BY IC			RECOVERY OF Cl AS HCl		
								Cl^- Concentration			Cl^- Recovered		
No.	Tube/Boat Material and Temp.	Water Vapor Conc.	Composition of Sample Injected	Vol. Inj. (μL)	Mass Cl Inj. (mg)	Vol. Imp. Solution (L)	Inj. No.	Meas. (mg/L)	Blank (mg/L)	Adj. (mg/L)	Mass (mg)	Mean(mg) [%RSD]	Percent Recov.
23	INCONEL 900°C	2.4%	Blank (EtOH)	5		0.025	1	1.521					
			6.6% CH_2Cl_2/EtOH	5	0.234	0.025	2	7.101	0.887	6.214	0.1554	0.1501 [4.7%]	64.1%
							3	6.659	0.887	5.772	0.1443		
							4	6.597	0.887	5.710	0.1428		
							5	6.844	0.887	5.957	0.1489		
							6	7.250	0.887	6.363	0.1591		
			Blank (EtOH)	5		0.025	7	0.252					
24	INCONEL 900°C	0%	Blank (H_2O,EtOH)	5,5		0.025	1	0.169					
			9.5% NaCl/H_2O EtOH	5 5	0.319	0.025	2	0.442	0.808	0.000	0.0000	0.0160 [58%]	5.0%
							3	1.761	0.808	0.953	0.0238		
							4	1.482	0.808	0.674	0.0169		
							5	1.652	0.808	0.844	0.0211		
							6	1.537	0.808	0.729	0.0182		
			Blank (H_2O,EtOH)	5,5		0.025	7	1.447					

(continued)

TABLE A-1. (Continued)

RUN	SAMPLE COLLECTION							ANALYSIS BY IC			RECOVERY OF Cl AS HCl		
								Cl^- Concentration			Cl^- Recovered		
No.	Tube/Boat Material and Temp.	Water Vapor Conc.	Composition of Sample Injected	Vol. Inj. (μL)	Mass Cl Inj. (mg)	Vol. Imp. Solution (L)	Inj. No.	Meas. (mg/L)	Blank (mg/L)	Adj. (mg/L)	Mass (mg)	Mean(mg) [%RSD]	Percent Recov.
25	INCONEL 900°C	2.4%	Blank (H_2O,EtOH)	5,5		0.025	1	0.527					
			9.5% NaCl/H_2O EtOH	5 5	0.319	0.025	2	6.542	1.351	5.191	0.1298	0.1447 [10.1%]	45.4%
							3	7.727	1.351	6.376	0.1594		
							4	7.550	1.351	6.199	0.1550		
							5	6.738	1.351	5.387	0.1347		
			Blank (H_2O,EtOH)	5,5		0.025	6	2.175					
26	INCONEL 900°C	2.4%	Blank (H_2O,EtOH)	5,5		0.025	1	0.140					
			9.5% NaCl/H_2O EtOH	5 5	0.319	0.025	2	9.885	0.293	9.592	0.2398	0.2649 [8.2%]	83.1%
							3	11.39	0.293	11.10	0.2775		
							4	11.39	0.293	11.10	0.2775		
			Blank (H_2O,EtOH)	5,5		0.025	5	0.445					

(continued)

TABLE A-1. (Continued)

RUN	SAMPLE COLLECTION							ANALYSIS BY IC			RECOVERY OF Cl AS HCl		
								Cl^- Concentration			Cl^- Recovered		
No.	Tube/Boat Material and Temp.	Water Vapor Conc.	Composition of Sample Injected	Vol. Inj. (μL)	Mass Cl Inj. (mg)	Vol. Imp. Solution (L)	Inj. No.	Meas. (mg/L)	Blank (mg/L)	Adj. (mg/L)	Mass (mg)	Mean(mg) [%RSD]	Percent Recov.
27	INCONEL 900°C	2.4%	Blank (H_2O,EtOH)	5,5		0.025	1	0.105					
			9.5% NaCl/H_2O EtOH	5 5	0.319	0.025	2	11.13	0.166	10.96	0.2740	0.266 [6.2%]	83.4%
							3	11.26	0.166	11.09	0.2773		
							4	10.03	0.166	9.86	0.247		
			Blank (H_2O,EtOH)	5,5		0.025	5	0.226					
28	INCONEL 900°C	2.4%	Blank (H_2O,EtOH)	5,5		0.025	1	0.548					
			9.5% NaCl/H_2O EtOH	5 5	0.319	0.025 [15 min]	2	8.055	0.482	7.573	0.1893	0.2036 [9.9%]	63.8%
							3	9.193	0.482	8.711	0.2178		
						0.025 [25 min]	4	10.67	0.482	10.18	0.2545	0.252 [1.3%]	79.0%
							5	10.47	0.482	9.99	0.250		
						0.025 [35 min]	6	10.84	0.482	10.36	0.2590	0.2574 [0.9%]	80.7%
							7	10.71	0.482	10.23	0.2558		
			Blank (H_2O,EtOH)	5,5		0.025	8	0.416					

(continued)

TABLE A-1. (Continued)

RUN	SAMPLE COLLECTION							ANALYSIS BY IC			RECOVERY OF Cl AS HCl		
								Cl⁻ Concentration			Cl⁻ Recovered		
No.	Tube/Boat Material and Temp.	Water Vapor Conc.	Composition of Sample Injected	Vol. Inj. (μL)	Mass Cl Inj. (mg)	Vol. Imp. Solution (L)	Inj. No.	Meas. (mg/L)	Blank (mg/L)	Adj. (mg/L)	Mass (mg)	Mean (mg) [%RSD]	Percent Recov.
29	INCONEL 900°C	0%	Blank (H_2O, EtOH)	5,5		0.025	1	0.417					
			11.8% KCl/H_2O EtOH	5 5	0.319	0.025	2	0.394	0.969	0.000	0.0000	0.0059 [140%]	1.8%
							3	0.897	0.969	0.000	0.0000		
							4	0.873	0.969	0.000	0.0000		
							5	1.454	0.969	0.485	0.0121		
							6	1.663	0.969	0.694	0.0174		
			Blank (H_2O, EtOH)	5,5		0.025	7	1.520					
30	INCONEL 900°C	2.4%	Blank (H_2O, EtOH)	5,5		0.025	1	0.987					
			11.8% KCl/H_2O EtOH	5 5	0.319	0.025	2	2.537	0.962	1.575	0.0394	0.0593 [21.2%]	18.6%
							3	3.685	0.962	2.723	0.0681		
							4	3.620	0.962	2.658	0.0665		
							5	3.692	0.962	2.730	0.0683		
							6	3.126	0.962	2.164	0.0541		
			Blank (H_2O, EtOH)	5,5		0.025	7	0.937					

(continued)

TABLE A-1. (Continued)

RUN	SAMPLE COLLECTION							ANALYSIS BY IC			RECOVERY OF Cl AS HCl		
								Cl^- Concentration			Cl^- Recovered		
No.	Tube/Boat Material and Temp.	Water Vapor Conc.	Composition of Sample Injected	Vol. Inj. (μL)	Mass Cl Inj. (mg)	Vol. Imp. Solution (L)	Inj. No.	Meas. (mg/L)	Blank (mg/L)	Adj. (mg/L)	Mass (mg)	Mean(mg) [%RSD]	Percent Recov.
31	INCONEL 900°C	0%	Blank (H_2O,EtOH)	10,5		0.025	1	0.273					
			6.2% $FeCl_3/H_2O$ EtOH	10 5	0.436	0.025	2	0.274	1.357	0.000	0.0000	0.0226 [85%]	5.2%
							3	1.673	1.357	0.316	0.0079		
							4	2.204	1.357	0.847	0.0212		
							5	3.010	1.357	1.653	0.0413		
							6	3.068	1.357	1.711	0.0428		
			Blank (H_2O,EtOH)	10,5		0.025	7	2.440					
32	INCONEL 900°C	2.4%	Blank (H_2O,EtOH)	10,5		0.025	1	0.422					
			6.2% $FeCl_3/H_2O$ EtOH	10 5	0.436	0.025	2	12.84	0.818	12.02	0.3005	0.2969 [7.0%]	68.1%
							3	13.07	0.818	12.25	0.3063		
							4	12.69	0.818	11.87	0.2968		
							5	13.54	0.818	12.72	0.3180		
							6	11.33	0.818	10.51	0.2628		
			Blank (H_2O,EtOH)	10,5		0.025	7	1.213					

(continued)

TABLE A-1. (Continued)

RUN	SAMPLE COLLECTION							ANALYSIS BY IC			RECOVERY OF Cl AS HCl		
								Cl^- Concentration			Cl^- Recovered		
No.	Tube/Boat Material and Temp.	Water Vapor Conc.	Composition of Sample Injected	Vol. Inj. (μL)	Mass Cl Inj. (mg)	Vol. Imp. Solution (L)	Inj. No.	Meas. (mg/L)	Blank (mg/L)	Adj. (mg/L)	Mass (mg)	Mean (mg) [%RSD]	Percent Recov.
33	INCONEL 900°C	2.4%	Blank (H_2O, EtOH)	5,5		0.025	1	0.276					
			4-6% NaOCl Soln. EtOH	5 5	Unknown	0.025	2	11.68	0.335	11.34	0.2835	0.2934 [10.8%]	
							3	11.49	0.335	11.16	0.2790		
							4	14.32	0.335	13.98	0.3495		
							5	11.19	0.335	10.85	0.2713		
							6	11.69	0.335	11.35	0.2838		
			Blank (H_2O, EtOH)	5,5		0.025	7	0.394					
34	INCONEL 900°C	2.4%	Blank (H_2O, EtOH)	40, 10		0.025	1	0.346					
			Organic Real-World Waste	50	Unknown	0.025	2	11.52	0.722	10.79	0.2698	0.3191 [9.5%]	
							3	14.54	0.722	13.82	0.3456		
							4	13.92	0.722	13.20	0.3300		
							5	14.28	0.722	13.55	0.3388		
							6	13.19	0.722	12.46	0.3116		
			Blank (H_2O, EtOH)	40, 10		0.025	7	1.098					

(continued)

TABLE A-1. (Continued)

RUN	SAMPLE COLLECTION							ANALYSIS BY IC			RECOVERY OF Cl AS HCl		
								Cl^- Concentration			Cl^- Recovered		
No.	Tube/Boat Material and Temp.	Water Vapor Conc.	Composition of Sample Injected	Vol. Inj. (μL)	Mass Cl Inj. (mg)	Vol. Imp. Solution (L)	Inj. No.	Meas. (mg/L)	Blank (mg/L)	Adj. (mg/L)	Mass (mg)	Mean(mg) [%RSD]	Percent Recov.
35	INCONEL 900°C	2.4%	Blank (H_2O,EtOH)	5,5		0.025	1	1.561					
			Inorganic Real-World Waste EtOH	5 5	Unknown	0.025	2	2.932	1.032	1.900	0.0475	0.0840 [24.7%]	
							3	4.586	1.032	3.554	0.0889		
							4	4.819	1.032	3.787	0.0947		
							5	4.664	1.032	3.632	0.0908		
							6	4.960	1.032	3.928	0.0982		
			Blank (H_2O,EtOH)	5,5		0.025	7	0.502					